(44)

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
5 April 2001 (05.04.2001)

PCT

(10) International Publication Number
WO 01/23527 A1

(51) International Patent Classification[7]: C12N 5/00, 5/06

(21) International Application Number: PCT/EP00/09453

(22) International Filing Date:
27 September 2000 (27.09.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
A 1659/99 28 September 1999 (28.09.1999) AT

(71) Applicant: **BAXTER AKTIENGESELLSCHAFT** [AT/AT]; Industriestrasse 67, A-1221 Wien (AT).

(72) Inventors: **REITER, Manfred**; Gebrüder-Lang-Gasse 11/17, A-1150 Vienna (AT). **MUNDT, Wolfgang**; Florianigasse 57/1/2/6, A-1080 Vienna (AT). **DORNER, Friedrich**; Peterlinigasse 17, A-1230 Vienna (AT). **GRILLBERGER, Leopold**; Dresdnerstrasse 51/8, A-1200 Vienna (AT). **MITTERER, Artur**; Schwarzeckerweg 10, A-2304 Orth (AT).

(74) Common Representative: **BAXTER AKTIENGESELLSCHAFT**; Industriestrasse 67, A-1220 Vienna (AT).

(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*
— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 01/23527 A1

(54) Title: MEDIUM FOR THE PROTEIN-FREE AND SERUM-FREE CULTIVATION OF CELLS

(57) Abstract: A medium is described for the protein-free and serum-free cultivation of cells, especially mammalian cells, whereby the medium contains a proportion of soy hydrolysate.

Medium for the protein-free and serum-free cultivatinon of cells

The invention pertains to a medium for the protein-free and serum-free cultivation of cells.

The cultivation of cells, especially eukaryotic cells or mammalian cells, constantly calls for the use of special culture media that make available to the cells the nutrient substances and growth substances that are required for efficient growth and for the production of the proteins that are desired. As a rule, serum or compounds that are derived from serum (e.g. bovine serum) are used as a component of the medium in this regard.

However, in the case of the use of serum or protein additives that are derived from human or animal sources in cell cultures, numerous problems exist, especially if the starting material for the preparation of a medicinal agent that is to be administered to humans is made available via the cell culture.

In the case of such serum preparations, therefore, the composition and quality already vary from batch to batch just because of the dissimilarity of the donor organisms for such preparations. This represents a considerable problem, especially for the standardization of cell production and in establishing standard growth conditions for such cells. However, intensive and constant quality control of the serum material that is used is required in every case. However, this is extremely time-consuming and cost intensive, especially in the case of such complex compositions as serum.

Moreover, such complex preparations contain a plurality of proteins that can act in a disruptive manner, especially within the context of the purification process for the recombinant protein that is to be recovered from the cell culture. This applies particularly to those proteins that are homologous with or similar to the protein that is to be recovered. Naturally, these problems are especially acute in the

because the biogenic pendant in the medium that is used (e.g., bovine protein) can be removed reliably within the context of purification only via quite specific differential purification (e.g., with antibodies that are directed specifically only against the recombinant protein but not against the bovine protein (Björck, L., J. Immunol., 1988, Vol. 140, pp. 1194-1197; Nilson et al., J. Immunol Meth., 1993, 164, pp. 33-40).

However, a pronounced problem in the use of serum or compounds which are derived from serum in the culture medium is also the risk of contamination by mycoplasma, viruses or BSE agents. In connection with preparations that are derived from human blood, the risk of contamination by viruses, such as hepatitis or HIV, has to be stressed in particular in this connection. In the case of serum or serum components that are derived from bovine material, the danger exists, in particular, of BSE contamination. In addition to this, all the serum-derived materials can, moreover, be contaminated with disease-inducing agents that are as yet unknown.

The addition of serum components in order to guarantee adequate adhesion of the cells to their surfaces and to guarantee adequate production of the desired substances from the cells has, apart from a few exceptions, been previously regarded as indispensable precisely for the cultivation of cells on solid surfaces. Thus with the method that is described in WO 91/09935, for example, it has been possible to achieve a process for the serum-free and protein-free cultivation of the FSME virus/virus antigen by means of the serum-free and protein-free cultivation of surface-dependant permanent cells, preferably vero cells (see WO 96/15231). However these are not recombinant cells but, rather, host cells that are used for the production of virus antigen in a lytic process.

In contrast to this, the cells that are used preeminently for a recombinant preparation, for example CHO cells, are capable of adhering only to a limited

extent. Thus, CHO cells that have been bred by conventional methods bind to both smooth and porous microcarriers only under serum-containing conditions (see US 4,973,616; Cytotechnology 9 (1992), 247-253). However, if such cells are bred under serum-free conditions, they lose this property and do not adhere to smooth carriers, or they become detached with ease therefrom if other adhesion-promoting additions, such as e.g., fibronectin, insulin or transferrin, have not been provided in the medium. However these are also proteins that are derived from serum.

Alternatively to this, the cells can be bred using the suspension culture technique as well as e.g., using the batch process or using a continuous culture technique. Cultivation preferably takes place using the chemostat process (Ozturk S.S. et al., 1996, Abstr. Pap. Am. Chem. Soc., BIOT 164, Payne G.F. et al., in "Large Scale Cell Culture Technology," 1987, ed. Lydersen B.K., Hauser publishers; pp. 206-212).

Kattinger H. et al (Advances Mol. Cell. Biology, 1996, 15A, 193-207) describe the long term cultivation of cells in protein-free medium, but these cells must be cultivated on carriers and do not leave alternatives as continuous culture techniques. It is stated that these cells only show long term stability when adhered to the surface of carriers because of reduced growth and, as a consequence, reduced demand for growth factors.

In addition, attempts have been made on several occasions in the prior art to adapt cells to a protein-free medium starting from serum-containing conditions. However, in the case of such adaptation, it has been found repeatedly that, compared to serum-containing conditions, the yield of expressed protein and the productivity of the recombinant cells are markedly reduced in the protein-free medium following adaptation (Appl. Microbiol. Biotechnol. 40 (1994), 691-658).

It has also been found that, in the case of a high cell density, the production of recombinant proteins is considerably restricted on occasions. During attempts to adapt the cells to protein-free or serum-free media, instability with reduced growth of the cells, which are used, is also found repeatedly so that cells with reduced expression are produced, or even nonproducing cells are produced, whereby these have a growth advantage, relative to the producing cells, in protein-free and serum-free media, and this leads to the fact that these overgrow the producing cells and then, finally, the entire culture now generates very low product yields.

SUMMARY OF THE INVENTION

The present invention has therefore an objective of improving the possibilities for the protein-free and serum-free cultivation of recombinant cells and of making agents and processes available with which recombinant cells can be cultivated efficiently in a serum-free or protein-free manner. Moreover, it should then be possible not only to culture surface-dependent cells, but also to use the suspension culture technique, whereby instability in the productivity of the cells is required to be repressed as much as possible.

A further objective of the present invention additionally is to efficiently increase the production of recombinant cells.

Finally, in accordance with the invention, the adaptation of recombinant cells to serum-free and protein-free media is required to be improved and configured more efficiently.

In accordance with the invention, these tasks are accomplished by means of a medium for the protein-free and serum-free cultivation of cells, especially mammalian cells, characterized by the feature that the medium contains a proportion of soy hydrolysate.

Surprisingly, it has been possible to show that the objectives, which were defined above, can be achieved by cultivating cells in a medium that contains soy hydrolysate, without having to tolerate the disadvantages of serum-free cultivation which are described in the prior art. In contrast to other hydrolysates which are known in the prior art, such as for example wheat hydrolysates, rice hydrolysates or yeast hydrolysates, it has been found that only soy hydrolysate mediates the properties in accordance with the invention and leads, for example, to a significantly increased yield of the recombinant target protein. When dealing with these terms, either the term soy hydrolysate or the term soy peptone can be used whithout having different meanings.

The medium in accordance with the invention preferably contains soy hydrolysate in a quantity of more than 10 wt% based on the total dry weight of the medium. As a rule, the soy hydrolysate in the medium is provided in a quantity of 4-40%.

The choice of specific soy hydrolysate is not critical in accordance with the invention. A plurality of soy preparations, which are to be found on the market, can be used in accordance with the invention, e.g., peptones from soy flour, digested enzymatically (e.g., by papain), with a pH value between 6.5 and 7.5 and a total nitrogen content between 9% and 9.7% and an ash content between 8 and 15%. These are peptones from soybeans in the form in which they are generally used for cell culture by the expert in the field.

In accordance with a preferred form of embodiment, use is made of a purified preparation of a soy hydrolysate or a crude fraction thereof in the medium in accordance with the invention. Impurities which could interfere with efficient cultivation are preferably eliminated during this purification, or the precision of the hydrolysate is improved, e.g., in regard to the molecular weight.

In accordance with the invention, the provision of an ultrafiltration step has proven to be especially valuable in practice during this purification; because of this, the use of ultrafiltered soy hydrolysate is especially preferred in the medium in accordance with the invention.

Ultrafiltration can take place in accordance with the process as described comprehensively in the prior art, e.g., with use being made of membrane filters with a defined cut-off limit.

The purification of the ultrafiltered soy peptone can take place by means of gel chromatography, e.g., by means of Sephadex chromatography, for example, with Sephadex G25 or Sephadex G10 or equivalent materials, ion-exchange chromatography, affinity chromatography, size exclusion chromatography or "reversed-phase" chromatography. These are processes from the prior art with which the expert in the field is familiar. Using this method, those fractions can be selected which contain soy hydrolysate of defined molecular weight, i.e. $\leq$1000 Dalton, preferably $\leq$500 Dalton, more preferably $\leq$350 Dalton.

Therefore the invention also comprises a process for producing a serum-free and protein-free cell culture medium, comprising obtaining a soy hydrolysate, ultrafiltering said soy hydrolysate using an ultrafiltration process, purifying said soy hydrolysate fraction using size exclusion chromatography and selecting the soy hydrolysate fractions consisting of soy hydrolysate having a molecular weight $\leq$1000 Dalton, preferably $\leq$500 Dalton, more preferably $\leq$350 Dalton.

An especially advantageous soy hydrolysate is characterized by the feature that it has a free amino acids content of between 10.3 and 15.6% or, preferably, between 12 and 13.5%, a total nitrogen content of between 7.6 and 11.4% or, preferably, between 8.7 and 9.5% and an endotoxin content of <500 U/g and whereby at least 40% or, preferably, at least 50% or, especially

preferably, at least 55% thereof has a molecular weight of 200-500 daltons and at least 10% or, preferably, 15% thereof has a molecular weight of 500-1000 daltons. Most preferably, at least 90% of the soy hydrolysate is of a molecular weight of $\leq$500 Daltons.

Such a soy hydrolysate is especially well suited to the industrial production of recombinant proteins since, because of its special features, it can be standardized especially easily and it is usable in routine processes.

In addition to soy hydrolysate, the medium in accordance with the invention can also contain synthetic media in a way that is known as such, such as e.g., DMEM/HAM's F12, Medium 199 or RPMI, that are adequately known from the literature.

Moreover, the medium in accordance with the invention also preferably contains amino acids, preferably those selected from the group comprising L-asparagine, L-cysteine, L-cystine, L-proline, L-tryptophan, L-glutamine, or mixtures thereof.

The following amino acids are also preferably added to the medium in accordance with the invention: L-asparagine (in a quantity of 0.001-1 g/L of medium, preferably 0.1-0.05 g/L, especially preferably 0.015-0.03 g/L); L-cysteine (0.001-1 g/L, preferably 0.005-0.05 g/L, especially preferably 0.01-0.03 g/L); L-cystine (0.001-1 g/L, preferably 0.01-0.05 g/L, especially preferably 0.015-0.03 g/L); L-proline (0.001-1.5 g/L, preferably 0.01-0.07 g/L, especially preferably 0.02-0.05 g/L); L-tryptophan (0.001-1 g/L, preferably 0.01-0.05 g/L, especially preferably 0.015-0.03 g/L); and L-glutamine (0.05-1 g/L, preferably 0.1-1 g/L).

The amino acids designated above can be added to the medium in accordance with the invention either individually or in combination. The combined addition of an amino acid mixture, which contains all of the above-mentioned amino acids, is especially preferred.

A serum-free and protein-free medium is used in a special form of embodiment, whereby this medium

additionally contains a combination of the above-mentioned amino acid mixture and purified ultrafiltered soy peptone.

Surprisingly, for example, it has been found that in order to inactivate viruses or other pathogens, the medium can be heated, without negative effects, for approximately 5-20 min or, preferably, 15 min at 70-95°C or, preferably, 85-95°C.

In accordance with the invention, every known synthetic medium can be used in combination with the soy hydrolysate. Conventional synthetic media can contain inorganic salts, amino acids, vitamins, a source of carbohydrates and water. For example, use can be made of DMEM/HAM's F12 medium. The concentration of soy extract in the medium can preferably be between 0.1 and 100 g/L, especially preferably, 1 and 5 g/L. In accordance with an especially preferred form of embodiment, soy peptone can be used which has been standardized in regard to its molecular weight. The molecular weight of the soy peptone preferably is less than 50 kD, especially preferably less than 10 kD, most preferably, less than 1 kD.

The addition of ultrafiltered soy peptone has proven to be especially advantageous for the productivity of the recombinant cell lines, whereby the average molecular weight of the soy peptone is 350 daltons (Quest Company). This is a soy isolate with a total nitrogen content of approximately 9.5% and a free amino acids content of approximately 13%.

The use of purified, ultrafiltered soy peptone with a molecular weight of $\leq$1,000 daltons, preferably $\leq$500 daltons, especially preferably $\leq$350 daltons is especially preferred.

The medium in accordance with the invention also preferably contains auxiliary substances, such as e.g., buffer substances, oxidation stabilizers, stabilizers to counteract mechanical stress, or protease inhibitors.

Use is especially made of a medium with the following composition: synthetic minimal medium (1-25 g/L), soy peptone (0.5-50 g/L), L-glutamine (0.05-1 g/L), $NaHCO_3$ (0.1-10 g/L), ascorbic acid (0.0005-0.05 g/L), ethanolamine (0.0005-0.05 g/L) and Na selenite (1-15 µg/L).

If required, a nonionic surfactant, such as, e.g., polypropylene glycol (PLURONIC F-61, PLURONIC F-68, SYNPERONIC F-68, PLURONIC F-71 or PLURONIC F-108) can be added to the medium as a defoaming agent in accordance with the invention.

This agent is generally used in order to protect the cells from the negative effects of aeration since, without an addition of a surfactant, the ascending and bursting air bubbles can lead to damage of those cells that are located on the surface of these air bubbles ("sparging") (Murhammer and Goochee, 1990, Biotechnol. Prog. 6:142-148).

The quantity of nonionic surfactant can hereby be between 0.05 and 10 g/L though, especially preferably, the smallest possible amount is between 0.1 and 5 g/L.

In addition, the medium in accordance with the invention can also contain cyclodextrin or a derivative thereof.

The serum-free and protein-free medium preferably contains a protease inhibitor, such as e.g., serine protease inhibitors, which are suitable for tissue culture and are of synthetic or plant origin.

Cells that have already been adapted are preferably used as the cells for cultivation in the medium in accordance with the invention, i.e., cells that have already adapted to growth in the protein-free and serum-free media. It has been found that not only can increased yields be achieved with such preadapted cells, but their stability for serum-free and protein-free cultivation is also clearly improved by the use of the medium in accordance with the invention.

However, recombinant cell clones have proven to be especially valuable in accordance with the invention, whereby these are stable from the outset for at least 40 generations and, preferably, at least 50 generations in serum-free and protein-free media, and express recombinant products.

Such cell clones are obtainable from a cell culture that is obtained following the cultivation of a recombinant original cell clone on a serum-containing medium and readaptation of the cells to a serum-free and protein-free medium.

The term "original cell clone" can be understood to mean a recombinant cell clone transfectant that, after transfection of the host cells with a recombinant nucleotide sequence, expresses a recombinant product in a stable manner under laboratory conditions. The original clone is bred in a serum-containing medium in order to optimize its growth. In order to increase its productivity, the original clone is bred, optionally in the presence of a selection agent, with selection on the selection marker and/or amplification marker. For large-scale industrial production, the original cell clone is bred, under serum-containing conditions of cultivation, to a high cell density and then it is readapted to a serum-free or protein-free medium just prior to the production phase. Cultivation preferably takes place without selection pressure in this case.

The cultivation of the recombinant original cell clone can take place from the beginning in a serum-free and protein-free medium; as a result, readaptation is no longer necessary. If required, use can also be made of a selection agent in this case and selection can take place on the selection marker and/or the amplification marker. A process for this is described in EP 0 711 835, for example.

The cell culture that is obtained after readaptation to a serum-free and protein-free medium is

tested for those cell clones of the cell population which produce products in a stable manner under serum-free and protein-free conditions, optionally in the absence of selection pressure. This can take place, for example, by means of immunofluorescence with marked specific antibodies which are directed against the recombinant polypeptide or protein. The cells that are identified as product producers are isolated from the cell culture and are re-bred under serum-free and protein-free conditions that are preferably equivalent to production conditions. The isolation of the cells can thereby take place by isolating the cells and testing them for product producers.

The cell culture, containing the stable cells, can be tested again for stable recombinant clones, and these are isolated from the cell culture and subcloned. The stable recombinant cell clones that are obtained under serum-free and protein-free conditions can then be bred further under serum-free and protein-free conditions.

The recombinant cell clones or the cell populations, which are prepared in this way in the medium in accordance with the invention, excel in particular by way of the feature that they are stable for at least 40 generations, preferably for at least 50 generations and, in particular, for more than 60 generations, and express a recombinant product.

An example of such a recombinant stable cell clone or cell population has been filed, in accordance with the Budapest convention, under number 98012206 with the ECACC (UK).

The cell culture, which is to be cultivated in accordance with the invention, is preferably derived from a recombinant mammalian cell. Recombinant mammalian cells can hereby be all those cells that contain sequences which code for a recombinant polypeptide or protein. All continuously growing cells, which grow either adherently or nonadherently, are encompassed in

this regard. Recombinant CHO cells or BHK cells are especially preferred. Recombinant polypeptides or proteins can be blood factors, growth factors or other biomedically relevant products.

In accordance with the present invention, cell clones are preferred which contain the coding sequence for a recombinant blood factor, such as Factor II, Factor V, Factor VII, Factor VIII, Factor IX, Factor X, Factor XI, Protein S, Protein C, an activated form of one of these factors, or vWF, and that are capable of expressing these in a stable manner over several generations. Recombinant CHO cells that express vWF or a polypeptide with vWF activity, Factor VIII or a polypeptide with VIII activity, vWF and Factor VIII, Factor IX or Factor II, are especially preferred in this regard.

30 generations are required in order to start a master cell bank. At least approximately 40 generations are required in order to carry out an average batch culture on the 1000-L scale. Starting out from an individual cell clone, it is possible with the medium in accordance with the invention to prepare a "master cell bank" (MCB) and a "working cell bank" (WCB) with approximately 8-10 generations, and hence a cell culture with up to 20-25 generations under protein-free and serum-free conditions on the production scale (production biomass) whereas, by contrast, some generations become unstable after growth on a serum-free or protein-free medium with previous cell clones and media and, as a result, a) a uniform cell culture with product producers is not possible and b) stable product productivity over an extended period of time is not possible.

However, in accordance with the invention, it was even possible, by contrast, to find increased product productivity even in comparison to the original cell clone that had been cultivated in a serum-containing medium.

In accordance with a further aspect, the present invention also pertains to a process for the cultivation of cells, especially mammalian cells, that is characterized by the feature that these cells are introduced into a medium in accordance with the invention and then are cultured in this medium.

Thus the present invention also pertains to the use of the medium in accordance with the invention for the cultivation of recombinant cells, preferably eukaryotic cells and, especially, mammalian cells.

The subject of the present invention, accordingly, is also a cell culture that comprises the medium in accordance with the invention and cells, preferably eukaryotic cells, and especially mammalian cells.

The invention will be elucidated in more detail by means of the following examples below, as well as by the figures in the drawings, but it is not to be limited thereto.

Fig. 1 shows the results of the cultivation of a rFVIII-CHO cell clone in a 10-L perfusion bioreactor:

a) Factor VIII activity (milliunits/mL) and the perfusion rate (1-5/day) over a period of 42 days;

b) volumetric productivity (units of Factor VIII/L/day) in the perfusion bioreactor;

Fig. 2 shows a comparison of the Factor VIII productivity (mU/mL) in the case of cultivation, using the batch process, of CHO cells which express rFactor VIII, in various media. Mix 1 consists of serum-free and protein-free medium without soy hydrolysate, but containing an amino acid mixture as listed in table 4; Mix 2 consists of serum-free and protein-free medium containing soy hydrolysate; Mix 3 consists of serum-free and protein-free medium containing soy hydrolysate and an amino acid mixture as listed in table 4 and Mix 4 consists of serum-free and protein-free medium containing 2.5g/l purified, ultrafiltrated soy

hydrolysate and an amino acid mixture as listed in table 4. For the purification of the ultrafiltrated soy hydrolysate a Sephadex® column was used.

Fig. 3 shows the Factor VIII productivity (U/L) in the case of the continuous growth of CHO cells, which express rFactor VIII, in a serum-free and protein-free medium after the start of the addition of purified, ultrafiltered soy peptone, namely on the 6th day of cultivation; and

Fig. 4 shows BHK cells expressing recombinant Factor II that have been bred in a protein-free and serum-free medium that contains soy hydrolysate.

Examples

Example 1:

Stability of rvWF-CHO cells after switching from a serum-containing medium to a serum-free and protein-free medium

CHO-dhfr cells were plasmid phAct-rvWF and pSV-dhfr co-transfected, and vWF-expressing clones were subcloned as described by Fischer et al. (1994, FEBS Letters 351:345-348). A working cell bank (WCB) was started from the subclones, which expressed rvWF in a stable manner, under serum-containing conditions but in the absence of MTX, and the cells were immobilized on a porous microcarrier (Cytopore®) under serum-containing conditions. Switching the cells to a serum-free and protein-free medium took place after a cell density of 2×10^7 cells/mL of the matrix had been reached. The cells were cultured further for several generations under serum-free and protein-free conditions. The cells were tested in a serum-free and protein-free medium at various points in time by means of immunofluorescence with labelled anti-vWF antibodies. The evaluation of the stability of the cells took place using the working cell bank prior to switching the medium, after 10 generations and after 60 generations in the serum-free and protein-free medium. Whereas the working cell bank still exhibited 100% rvWF producers,, the proportion of rvWF producers declined to approximately 50% after 10 generations in the serum-free and protein-free medium. After 60 generations, more than 95% of the cells were identified as nonproducers.

Example 2:

Cloning of stable recombinant CHO clones

A dilution series was prepared from the cell culture containing rvWF-CHO cells in accordance with Example 1 (this stable cell clone that was designated r-vWF-CHO F7 was filed, in accordance with the Budapest convention, with the ECACC (European Collection of Cell

Cultures), Salisbury, Wiltshire SP4 OJG, UK, on January 22, 1998, and acquired the deposition number 98012206) which had been cultured for 60 generations in a serum-free and protein-free medium and 0.1 cells were seeded out in each well of a microtiter plate. The cells were cultivated for approximately 3 weeks in DMEM/HAM's F12 without serum additions or protein additions and without selection pressure, and the cells were tested via immunofluorescence with labelled anti-vWF antibodies. A cell clone, which had been identified as positive, was used as the starting clone for the preparation of a seed cell bank. A master cell bank (MCB) was started from the seed cell bank in a serum-free and protein-free medium and individual ampules were put away and frozen for the further preparation of a working cell bank. A working cell bank was prepared in a serum-free and protein-free medium from an individual ampule. The cells were immobilized on porous microcarriers and cultivated further for several generations under serum-free and protein-free conditions. The cells were tested for productivity at various points in time in a serum-free and protein-free medium by means of immunofluorescence with labelled anti-vWF antibodies. The evaluation of the stability of the cells took place at the working cell bank stage and after 10 and 60 generations in a serum-free and protein-free medium. Approximately 100% of the cells were identified as positive stable clones, which express rvWF, at the working cell bank stage,after 10 generations ,and 60 generations.

Example 3:

Cell specific productivity of the recombinant cell clones

A defined number of cells was removed at defined stages during the cultivation of the recombinant cells, and these were incubated for 24 h with fresh medium. The rvWF: Risto-CoF-activity was determined in the supernatant liquors of the cell cultures. Table 1 shows

that, in the case of the stable recombinant cell clones in accordance with the invention, the cell-specific productivity was stable even after 60 generations in a serum-free and protein-free medium and it had even increased in comparison to the original clone that had been cultivated in a serum-containing medium.

Table 1

Cell Clone	Cell specific productivity of the working cells in mU rvWF/10^6 cells/day	Cell specific productivity after 10 generations in mU rvWF/10^6 cells/day	Cell specific productivity after 60 generations in mU rvWF/10^6 cells/day
rvWF-CHO #808.68 original cell clone	55	30	<10
r-vWF-CHO F7*) stable clone	62	65	60

*) filed on January 22, 1998 (ECACC (European Collection of Cell Cultures, Salisbury, Wiltshire SP4 OJG, UK); deposition number 98012206)

Example 4

Composition of a synthetic serum-free and protein-free medium:

Table 2

Component	g/L	Preferred quantity (according to our knowledge at the time of the patent application) in g/L
Synthetic minimal medium (DMEM/HAM's F12)	1 - 100	11.00 - 12.00
Soy peptone	0.5 - 50	2.5
L-glutamine	0.05 - 1	0.36
Ascorbic acid	0.0005 - 0.05	0.0035
$NaHCO_3$	0.1 - 10	2.00
Ethanolamine	0.0005 - 0.05	0.0015
Na selenite	1 - 15 µg/1	8.6 µg/1
Optionally: Synperonic F68	0.01 - 10	0.25

Example 5:

Cultivation of rFVIII-CHO cells in a protein-free and serum-free minimal medium

A cell culture containing rFVIII-CHO cells was cultivated in a 10-L stirred tank with perfusion. A medium in accordance with Example 4 was used in this case. The cells were thereby immobilized on a porous microcarrier (Cytopore®, Pharmacia) and then cultivated for at least 6 weeks. The perfusion rate was 4 volume changes per day; the pH was 6.9-7.2; the O_2 concentration was approximately 20-50% and the temperature was 37°C.

Figure 1 shows the results of the cultivation of a rFVIII-CHO cell clone in a 10 L perfusion bioreactor.

a) Factor VIII activity (milliunits/mL) and perfusion rate (1-5/day) over a period of 42 days.

b) Volumetric productivity (units of Factor VIII/L/day) in the perfusion bioreactor.

Table 3

Days of cultivation	Cell specific productivity (mU/10^6 cells/day)	Immunofluorescence (% FVIII positive cells)
15	702	n.a.
21	1125	n.a.
28	951	>95%
35	691	>95%
42	970	n.a.

Table 3 shows the stability and specific productivity of the rFVIII-expressing cells. In order to obtain these results, samples were taken after 15, 21, 28, 35 and 42 days and then centrifuged at 300 g and resuspended in fresh serum-free and protein-free medium. The Factor VIII concentration in the supernatant liquors of the cell cultures and the cell count was determined after a further 24 h. The specific FVIII productivity was calculated from these data.

A stable average productivity of 888 milliunits/10^6 cells/day was achieved. This stable productivity was also confirmed by immunofluorescence with labelled

anti-FVIII antibodies after 15, 21, 28, 35 and 42 days in a serum-free and protein-free medium.

Example 6:

Comparison of the productivity of recombinant FVIII-CHO cells in a protein-free and serum-free medium containing further medium components

A cell culture containing rFVIII-CHO cells was cultivated batchwise. In this case, use was made of a medium in accordance with Example 4 to which the following amino acids had been added:

Table 4

Amino acid:	mg/l	Preferred quantity (according to our knowledge at the time of the patent application) in mg/L
L-Asparagine	1-100	20
L-Cysteine·HCl·H_2O	1-100	15
L-Cystine	1-100	20
L-Proline	1-150	35
L-Glutamine	50 - 1000	240

The cells were bred at 37°C and pH 6.9-7.2. The cells were bred using the batch process over periods of 24-72 h.

The productivity of the recombinant FVIII-CHO cells was measured in the following medium compositions:

Mix 1: comprising a serum-free and protein-free medium without soy peptone and additionally containing an amino acid mixture in accordance with the table designated above.

Mix 2: comprising a serum-free and protein-free medium containing soy peptone.

Mix 3: comprising a serum-free and protein-free medium containing soy peptone and additionally containing an amino acid mixture in accordance with the

table designated above.

Mix 4: comprising a serum-free and protein-free medium, and additionally containing an amino acid mixture in accordance with the table designated above and 2.5 g/L of purified, ultrafiltered soy peptone. The purification of the ultrafiltered soy peptone took place chromatographically over a Sephadex® column.

Example 7:

Cultivation of recombinant FVIII-CHO cells in a protein-free and serum-free medium using the chemostat culture method

A cell culture containing rFVIII-CHO cells was cultivated in a 10-L stirred bioreactor tank. In this case, use was made of a medium in accordance with Example 4, without soy peptone, containing an amino acid mixture in accordance with Example 6. The cells were bred at 37°C and pH 6.9-7.2; the oxygen concentration was 20-50% air saturation. Samples were taken every 24 h in order to determine the Factor VIII titer and the cell concentration in the supernatant liquor of the culture. The total cell concentration was constant from the 2nd day to the 14th day. Ultrafiltered soy peptone was added to the medium starting from the 6th day. The Factor VIII productivity, is illustrated in 3; the measurements took place by means of a CHROMOGENIX CoA FVIII:C/4 system. Immunofluorescence was carried out with labelled anti-FVIII antibodies. It can be seen from the data that a distinct increase in Factor VIII productivity and hence an increase in the volumetric productivity of the bioreactor system, occurred as a result of the addition of soy peptone, whereby this did not lead to a distinct increase in cell growth. The absence of soy peptone in the continuous culture leads to a distinct decline in Factor VIII productivity after a few days, whereas the addition of soy peptone leads, as a consequence, to an almost 10-fold increase in productivity. However, since this addition does not increase the cell count, it is hereby clearly shown that ultrafiltered soy peptone

leads, as a consequence, to a distinct increase in productivity which is independent of cell growth.

Example 8:

Comparison of the growth rate and the productivity of recombinant FVIII-CHO cells in a protein-free and serum-free medium containing different hydrolysates

A rFVIII-CHO cell culture was cultivated batchwise. In this case, use was made of a serum-free and protein-free medium as described in Example 4 to which different hydrolysates (from soy, yeast, rice and wheat) had been added. A serum-free and protein-free medium, to which no hydrolysate had been added, was used as the control.

The initial cell density was 0.6×10^5 and 0.4×10^6, respectively. The cells were cultured at 37°C using the batch process at pH 6.9-7.2.

Table 5: shows the results of the cultivation experiments with rFVIII-CHO cells in a serum-free and protein-free medium to which soy hydrolysate (ultrafiltered) and yeast hydrolysate had been added. The initial cell density was 0.6×10^5 cells. A serum-free and protein-free medium without hydrolysate additions was used as the control.

Table 5

Hydrolysate	Final cell density ($\times 10^6$/mL)	FVIII titer (mU/mL)	FVIII clotting activity (mU/mL)
Soy	3.6	485	508
Yeast	3.3	226	230

Table 6: shows the results of the cultivation experiments with rFVIII-CHO cells in a serum-free and protein-free medium to which soy hydrolysate (ultrafiltered), rice hydrolysate and wheat hydrolysate had been added. The initial cell density was 0.6×10^5 cells. A serum-free and protein-free medium without hydrolysate additions was used as the control.

Table 6

Hydroysate	Final cell density ($x10^6$/mL)	FVIII titer (mU/mL)	vWF - Antigen (µg/mL)
Soy	3.7	1142	6.7
Rice	3.0	479	3.2
Wheat	3.4	522	3.9
Control	3.0	406	3.1

Table 7: shows the results of the cultivation experiments with rFVIII-CHO cells in a serum-free and protein-free medium to which soy hydrolysate (ultrafiltered) and wheat hydrolysate had been added. The initial cell density amounted to 0.4 x 10^6 cells.

Table 7

Hydrolysate	Final cell density ($x10^6$/mL)	FVIII titer (mU/mL)	FVIII-Antigen (µg/mL)	VWF-Antigen (µg/mL)
Soy	1.6	1427	166	17.2
Wheat	1.0	1120	92	7.9

Example 9:

Cultivation of BHK cells in a protein-free and serum-free medium containing soy hydrolysate

BHK-21 (ATCC CCL 10) cells were co-transfected three times with the following plasmids by means of a $CaPO_4$ procedure: 25 µg of the plasmid pSV-FII (Fischer, B. et al., J. Biol. Chem., 1996, Vol. 271, pp. 23737-23742) which contains the human Factor II (prothrombin)-cDNA under the control of a SV40 promotor (SV40 early gene promoter); 4 µg of the plasmid pSV-DHFR for methotrexate resistance and 1 µg of the plasmid pUCSV-neo (Schlokat, U. et al., Biotech. Appl. Biochem., 1996, Vol. 24, pp. 257-267) which mediates G418/neomycin resistance. Stable cell clones were selected by means of cultivation in a medium, which contained 500 µg/mL of

G418, by increasing the methotrexate concentration in a stepwise manner up to a concentration of 3 μM.

The clones that were obtained in this way were subcloned and adapted to a protein-free and serum-free medium. Cultivation took place using the suspension culture technique.

The results can be seen in Table 6; the BHK cells, which were bred in the protein-free and serum-free medium containing soy hydrolysate, exhibited a high and stable rate of production of recombinant Factor II.

Claims

1. A protein-free and serum-free medium for the cultivation of cells, comprising soy hydrolysate wherein at least 40% of said soy hydrolysate has a molecular weight of $\leq$ 500 Dalton.

2. A medium in accordance with claim 1 wherein said medium contains a quantity in excess of 10 wt% soy hydrolysate based on the total dry weight of the medium.

3. A medium in accordance with claim 1, wherein said medium contains ultrafiltered soy hydrolysate.

4. A medium in accordance with claim 3, wherein said medium contains purified soy hydrolysate.

5. A medium in accordance with claim 1, wherein the soy hydrolysate has an endotoxin content of <500 U/g.

6. A medium in accordance with claim 1, wherein at least 50% of the soy hydrolysate has a molecular weight of $\leq$500 daltons.

7. A medium in accordance with claim 6, wherein at least 55% of the soy hydrolysate has a molecular weight of $\leq$500 daltons.

8. A medium in accordance with claim 1, wherein said medium also contains an amino acid.

9. A medium in accordance with claim 7, wherein said amino acid is selected from the group consisting of L-asparagine, L-cysteine, L-cystine, L-proline, L-tryptophan, L-glutamine or mixtures thereof.

10. A medium in accordance with claim 1 wherein said medium also contains auxiliary substances, selected from the group consisting of buffer substances, oxidation stabilizers, stabilizers to counteract mechanical stress, and protease inhibitors.

11. Use of a medium according to claim 1 for the cultivation of mammalian cells.

12. Use of a medium according to claim one for the cultivation of mammalian cells selected from the group consisting of CHO cells and BHK cells.

13. A process for the cultivation of cells, comprising

introducing said cells into a medium in accordance with claim 1 and

growing said cells in said medium.

14. A process for the production of a protein from cell culture comprising:

introducing cells into a medium in accordance with claim 1, wherein said cells express a desired protein;

growing said cells in said medium and expressing said protein, thereby producing a mixture of said cells and said protein in the medium;

purifiying said protein from said mixture.

15. A cell culture composition comprising mammalian cells and a medium in accordance with claim 1.

16. A process for producing a cell culture medium according to claim 1, comprising:

obtaining a soy hydrolysate,

ultrafiltering said soy hydrolysate using an ultrafiltration process

purifying said soy hydrolysate fraction using size exclusion chromatography,

selecting the soy hydrolysate fractions consisting of soy hydrolysate having a molecular weight $\leq$500 Dalton.

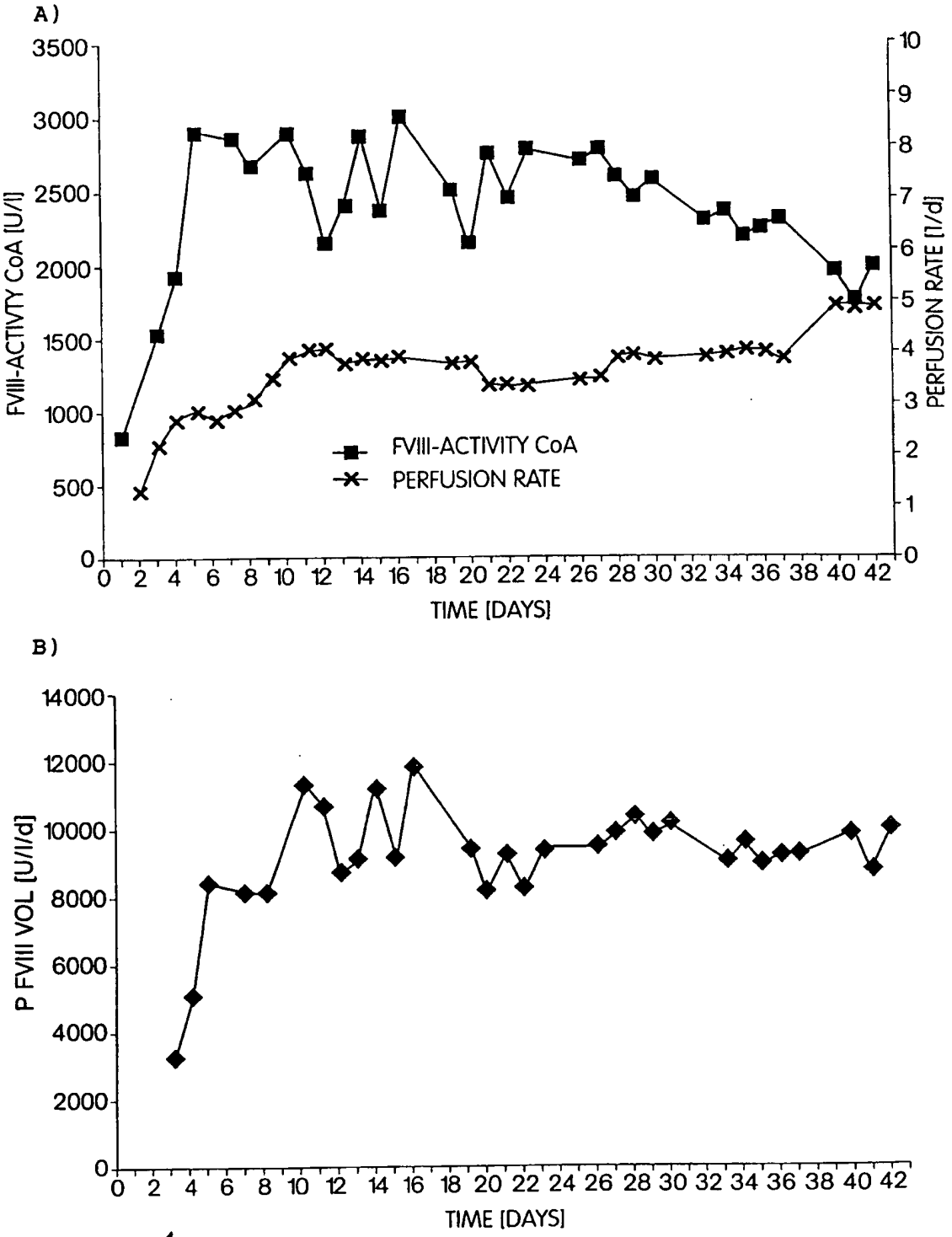
A)
FVIII-ACTIVTY CoA [U/l]
PERFUSION RATE [l/d]
FVIII-ACTIVITY CoA
PERFUSION RATE
TIME [DAYS]
B)
P FVIII VOL [U/l/d]
TIME [DAYS]

Fig. 1

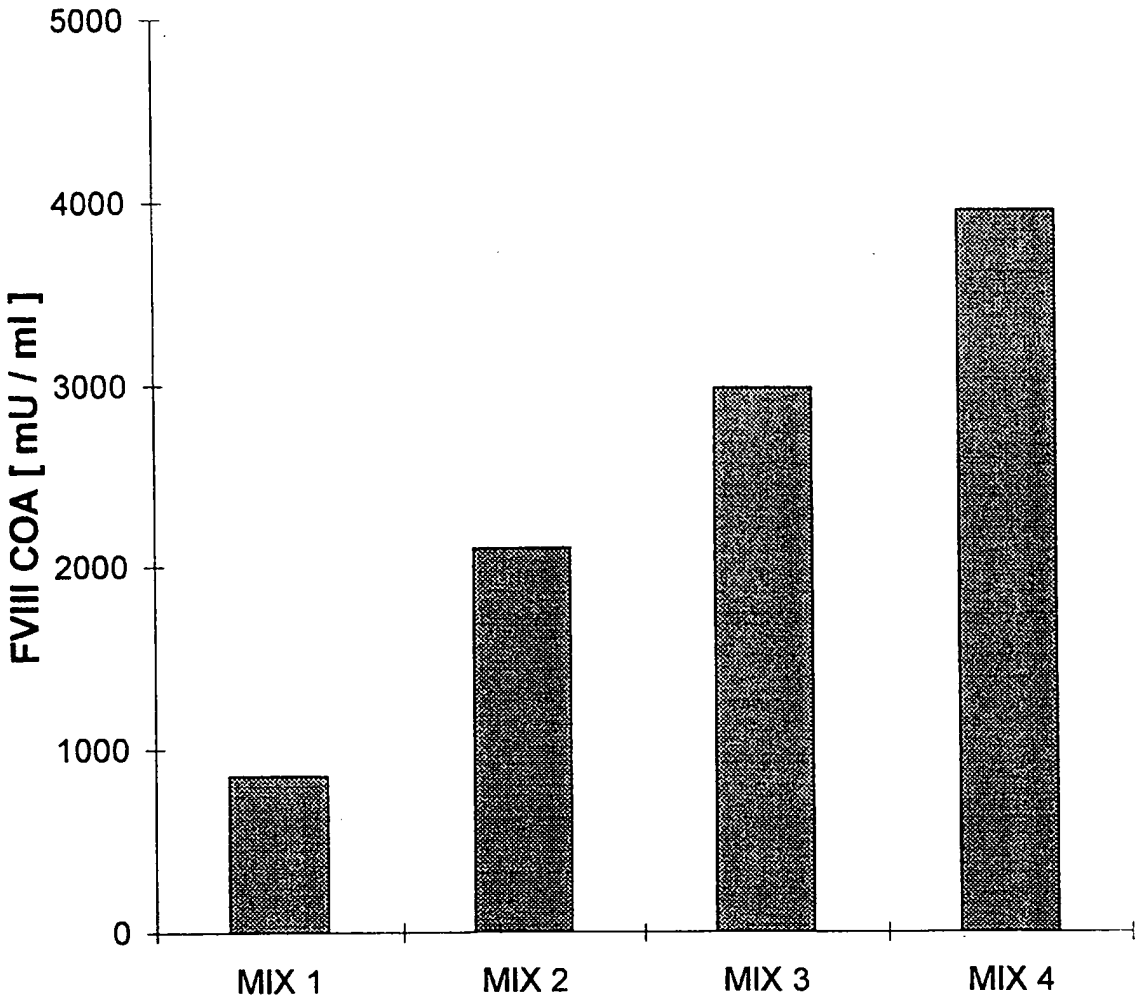

Fig. 2

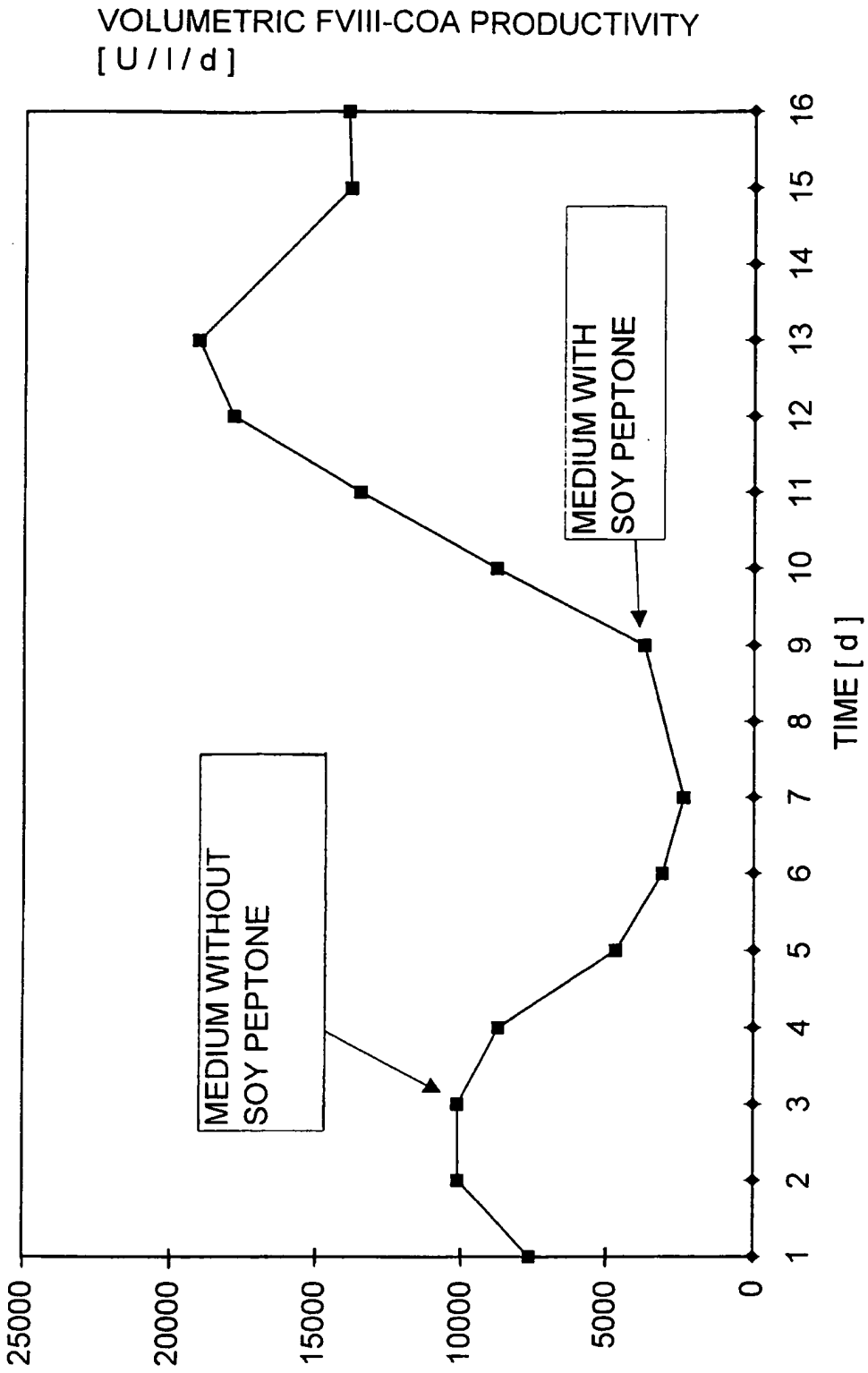
VOLUMETRIC FVIII-COA PRODUCTIVITY
[U / l / d]
25000
20000
15000
10000
5000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
TIME [d]
MEDIUM WITH SOY PEPTONE
MEDIUM WITHOUT SOY PEPTONE

FIG. 3

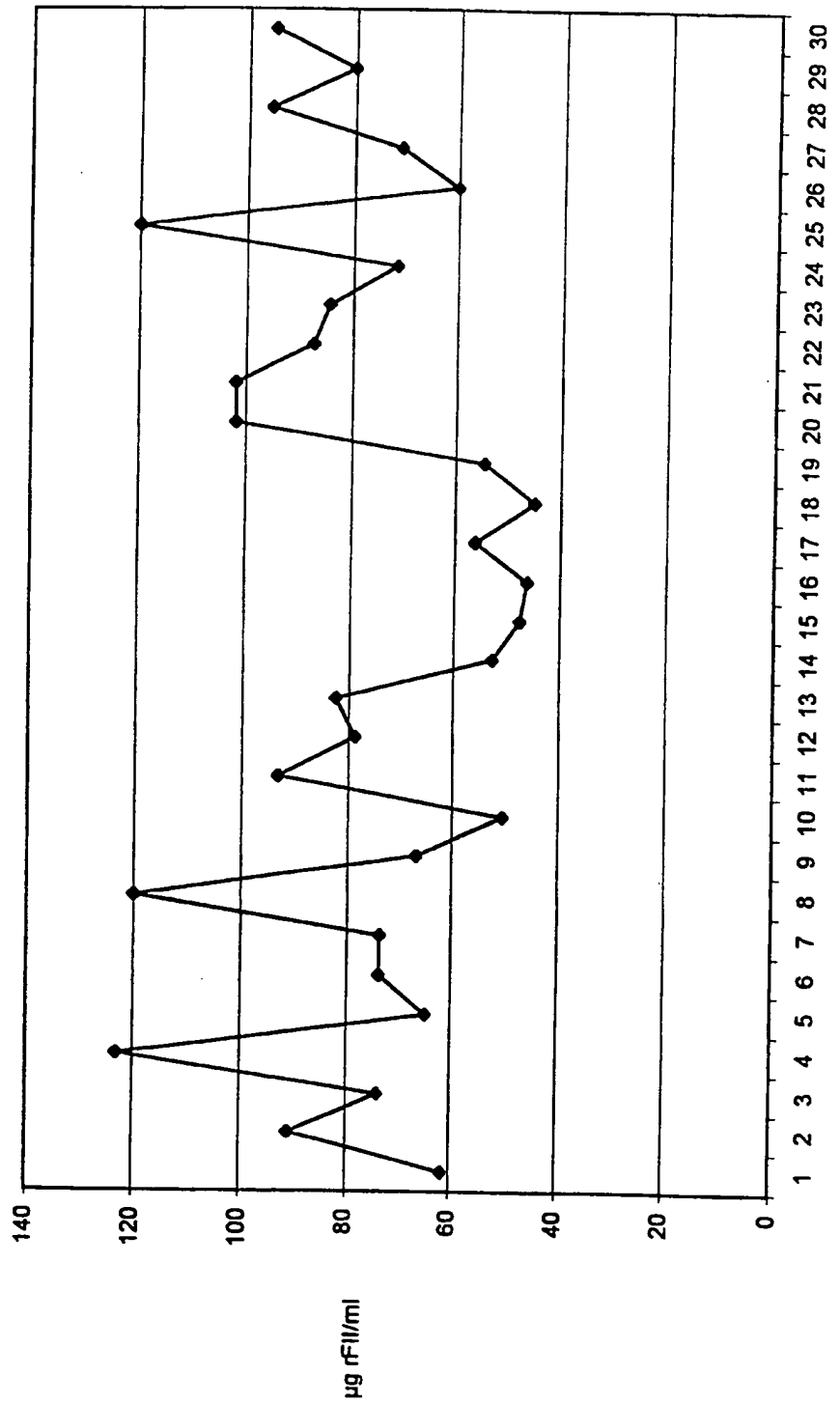
µg rFII/ml
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
DAYS

Fig. 4

INTERNATIONAL SEARCH REPORT

Inter onal Application No
PCT/EP 00/09453

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C12N5/00 C12N5/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C12N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ, MEDLINE, BIOSIS, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 15614 A (LIFE TECHNOLOGIES INC) 16 April 1998 (1998-04-16) example 2 ---	1-16
X	WO 98 08934 A (LIFE TECHNOLOGIES INC) 5 March 1998 (1998-03-05) example 3 ---	1-16
X	US 5 633 162 A (KEEN MICHAEL J ET AL) 27 May 1997 (1997-05-27) example 5 --- -/--	1-16

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 January 2001	25/01/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Nichogiannopoulou, A

2

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Inter ›nal Application No
PCT/EP 00/09453

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DATABASE WPI Section Ch, Week 199150 Derwent Publications Ltd., London, GB; Class B04, AN 1991-365003 XP002156904 & JP 03 244391 A (AJINOMOTO KK), 31 October 1991 (1991-10-31) abstract	1,8,10, 13,14
A	QUEST INTERNATIONAL PRODUCT INFORMATION, 'Online! 1998, XP002156903 Retrieved from the Internet: <URL:http://www.sheffield-products.com> 'retrieved on 2001-01-10! the whole document	1-7
P,X	WO 00 03000 A (CHUGAI PHARMACEUTICAL CO LTD) 20 January 2000 (2000-01-20) example 1	1-16

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter onal Application No
PCT/EP 00/09453

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9815614 A	16-04-1998	AU 4751697 A	05-05-1998
		EP 0954563 A	10-11-1999
		US 6103529 A	15-08-2000
WO 9808934 A	05-03-1998	AU 4330597 A	19-03-1998
		EP 0953041 A	03-11-1999
US 5633162 A	27-05-1997	US 5316938 A	31-05-1994
		AU 645615 B	20-01-1994
		AU 8591591 A	07-05-1992
		CA 2053586 A	18-04-1992
		EP 0481791 A	22-04-1992
		JP 2625302 B	02-07-1997
		JP 6070757 A	15-03-1994
		NZ 240248 A	25-11-1994
		ZA 9108249 A	16-04-1993
JP 3244391 A	31-10-1991	JP 2844484 B	06-01-1999
WO 0003000 A	20-01-2000	AU 6311099 A	01-02-2000